FIELD DENSITY BY THE SAND CONE METHOD

(A Modification of AASHO Designation T 191)

Scope

1. This method is used to determine the density of compacted soils or aggregates by determining the weight and moisture content of material removed from a test hole and measuring the volume of the test hole.

Apparatus

2. The following items will be necessary:

(a) Miscellaneous digging tools.

(b) Sand cone apparatus consisting of base plate, cone and sand jar. (See Fig. 1.)

(c) Standard sand obtained from warehouse. (Sand shall be kept dry and free flowing.)

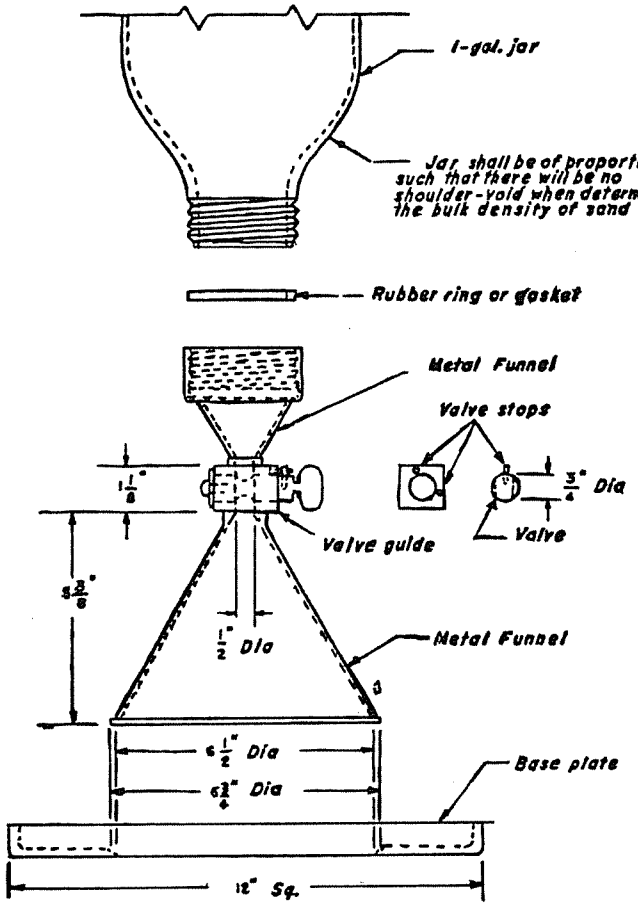


FIGURE 1
Density Apparatus

(d) Containers with air tight covers (cylinder cans are satisfactory).

(e) Oven, hot plate, stove or Speedy Moisture Tester.

NOTE: *Calibration of sand and sand cone apparatus shall be done in accordance with ARIZ 229.*

Preparation of Test Site

3. The surface of the area where the test is to be conducted shall be prepared as follows:

(a) Clean away all loose soil and rock from an area of about 3 feet square at the spot where the test is to be made. In areas compacted by sheeps foot rollers, it is necessary to get below the depth of the "foot" imprints.

(b) The top of the material at the chosen location shall be prepared to a plane and level surface for an area slightly larger than the size of the base plate. The base plate shall then be placed on this level surface.

(c) A hole shall be dug approximately the diameter of the hole in the base plate and to the desired depth. (Usually 6 inches to 8 inches.) While digging, especially using a hammer and chisel, care must be taken to avoid prying as this may deform the hole, disturb the surrounding material and give a false volume reading. All of the material removed from the hole shall be carefully recovered and put into a suitable container, also making sure to get the hole as clean as possible. The lid on the can shall then be sealed with masking tape. This operation shall be done quickly to avoid any excessive drying of the sample.

Suggested test hole volumes and corresponding moisture sample weights are given in Table I. There will be occasions where the values listed in Table I will be difficult to arrive at or follow, such as in the case where we are limited to a shallow depth of compacted material. This table is offered as a guide and should be followed in most cases; however, deviations from these values are allowable when conditions warrant. The "Speedy" Moisture Method (ARIZ 224) may be used to determine the moisture content. The "Speedy" Method will give the percent moisture on the passing No. 4 material. If the sample contains material retained on the No. 4 sieve the "Speedy" results must be adjusted in accordance with the following formula to obtain the percent moisture of the total sample.

$$W = \frac{w\ (100 - R) + R}{100}$$

Where:

W = % moisture in total sample
w = % moisture in Pass No. 4 material
R = % rock (Plus No. 4 sieve)

An example of this formula is shown under **Calculations** in this procedure.

TABLE I

Maximum Particle Size Retained	Minimum Test Hole Volume cu. ft.	Minimum Moisture Content Sample – grams
No. 4 Sieve	0.060	100
½ in.	0.060	250
1 in.	0.075	500
2 in.	0.100	1000
2½ in.	0.135	1500

Test Procedure

4. The volume of the hole is determined by the use of the sand cone in accordance with the following instructions:

(a) Place the previously filled and weighed sand-cone apparatus over the base plate with the cone down.

(b) Make sure there is no construction equipment operating in the **immediate** vicinity as any vibrations will cause a false volume determination.

(c) Open valve all the way and let the sand flow freely, being careful not to jar the apparatus while the sand is running. When the sand ceases to move in the bottle, close the valve and remove the apparatus.

(d) Re-claim any sand not contaminated by soil particles for future use.

(e) Weigh the sand cone apparatus with the remaining sand to determine the volume of the hole.

Reference to Method "A" Proctor

5. If referencing to Method "A" Proctor continue as follows:

(a) Weigh the total sample.

(b) Screen over 3" and No. 4 sieve.

(c) With a small brush clean as many fines from the rock as possible.

(d) If any rock is retained on the 3" sieve, verify this with a sieve analysis and call this the end point. This sieve analysis shall be reported with a note stating the density is not determinable due to the rock retained on a 3" sieve.

(e) Weigh and record the weight of the passing No. 4 material.

(f) Immediately weigh a moisture sample from the passing No. 4 material to be run either by "Speedy" or Hot Plate Method.

(g) Subtract the weight of passing No. 4 from the total weight of the sample and determine the weight and percent of rock.

(h) If the rock content is greater than 50% (or 60% in the case of Aggregate Base) report the sieve analysis with a note stating the density is not determinable due to excess rock.

NOTE: *When conditions prevent density determinations in areas due to the presence of excessive rock or rock retained on the 3" sieve, an attempt shall be made to compact these areas comparable to those surrounding locations where the required compaction was found through testing to be satisfactory.*

(i) If less than 50% (or 60% in the case of Aggregate Base) is retained on the No. 4 sieve, proceed with the folowing calculations.

Calculations

6. The calculations shall be as follows:

(a) Wt. of sand, in lb., to fill hole and funnel (W_s):

$$W_s = \frac{W_o - W_f}{453.6\ \text{g./lb.}}$$

Where:

W_o = original wt. of sand and apparatus, g.
W_f = final wt. of sand and apparatus, g.

Example:

$$W_s = \frac{(8560\ \text{g.}) - (4314\ \text{g.})}{453.6\ \text{g./lb.}}$$

$$= \frac{4246\ \text{g.}}{453.6\ \text{g./lb.}}$$

$$= 9.36\ \text{lb.}$$

(b) Volume, in cubic feet, of hole (V):

$$V = \frac{W_s}{D_s} - V_c$$

Where:

W_s = wt. of sand to fill hole and funnel, lb.
D_s = density of sand, lb./cu. ft.
V_c = volume of cone and base plate

Example:

$$V = \frac{(9.36 \text{ lbs.})}{(96.4 \text{ lb./cu. ft.})} - (.0407 \text{ cu. ft.})$$

$$= .0564 \text{ cu. ft.}$$

(c) Percent moisture of pass No. 4 material may be determined by utilizing the Speedy Test Method, ARIZ 224, or by oven-dry method (ARIZ 209).

$$w = \frac{W_w - W_d}{W_d} \times 100$$

Where:

W_w = weight of wet soil, g.
W_d = weight of dry soil, g.
w = % moisture in pass No. 4 material

Example:

$$w = \frac{(322 \text{ g.} - 289 \text{ g.})}{(289 \text{ g.} - 22 \text{ g.})} \times 100 = \frac{33 \text{ g.}}{267 \text{ g.}} \times 100$$

$$= 12.4\%$$

(d) Moisture content of the total sample expressed in percentage shall be calculated as follows:

$$W = \frac{w\,(100 - R) + R}{100}$$

Where:

W = % moisture in total sample
w = % moisture in Pass No. 4 material
R = % rock (Plus No. 4 sieve)

Example:

$w = 12.4\%$
$R = 29\%$

$$W = \frac{12.4\,(100 - 29) + 29}{100} = \frac{909.4}{100} = 9.1\%$$

The formula assumes that the rock has a moisture content of 1% and is sufficiently accurate to use in most cases. If the moisture content of the rock is appreciably above 2% as on absorbent materials, then the central laboratory should be contacted for instructions.

(e) Wet density, D_w in lb./cu. ft., of material:

$$D_w = \frac{W_t}{V}$$

Where:

W_t = weight of total sample, lb.

Example:

$$D_w = \frac{7.41 \text{ lbs.}}{.0564 \text{ cu. ft.}} = 131.4 \text{ lb./cu. ft.}$$

(f) Field dry density, D_d, in lb./cu. ft., of material:

$$D_d = \frac{D_w}{100 + W} \times 100$$

Example:

$$D_d = \frac{131.4 \text{ lb./cu. ft.}}{100 + 9.1} \times 100 = 120.4 \text{ lb./cu. ft.}$$

(g) % compaction $= \dfrac{D_d \times 100}{\text{Maximum Density (Corrected)}}$

Example:

(Reference is made to the example shown on the chart in the Rock Correction Method, ARIZ 227)

Maximum Dry Density (pass #4 material = 114 lb./cu. ft.

Percent rock = 29%

Corrected Maximum Dry Density = 122 lb./cu. ft.

NOTE: *Compaction shall be reported to the nearest whole percent.*

$$\% \text{ compaction} = \frac{120.4 \text{ lb./cu. ft.} \times 100}{122.0 \text{ lb./ cu. ft.}}$$

$$= 99\%$$

Reference to Method "C" or Method "D" Proctor

7. If referencing to Method "C" or "D" Proctor continue as follows: (For use only on Volcanic Cinders or Light Porous Materials.)

(a) Weigh and record the total sample.

(b) Screen the sample over a No. 4 sieve as rapidly as possible so that moisture will not be lost.

(c) Determine the percent of rock retained on the No. 4 sieve.

(d) If more than 50% and less than 60% is retained on the No. 4 sieve, it is necessary to reference to Method "D" Proctor.

If less than 50% is retained on the No. 4 sieve, it is necessary to reference to Method "C" Proctor.

If more than 60% is retained on the No. 4 sieve, report the sieve analysis with a note stating the density is not determinable due to excess material retained on the No. 4 sieve.

(e) Recombine the passing No. 4 material with the rock (material retained on the No. 4 sieve) and remix this to a uniform basis.

(f) Take a portion of this sample for moisture determination, and determine percent moisture by ARIZ 209. The "Speedy" method may be used if the sample contains 100% passing No. 4 sieve. The "Speedy" method shall not be used if material is retained on the No. 4 sieve, as the moisture correction formula $W = \frac{w(100 - R) + R}{100}$ is not accurate for Volcanic Cinders and lightporous materials.

Calculations

8. The calculations shall be as follows:

(a) Percent moisture in sample:

$$W = \frac{W_w - W_d}{W_d} \times 100$$

Example:

$$W = \frac{(322 \text{ g.} - 305 \text{ g.})}{(305 \text{ g.} - 22 \text{ g.})} \times 100 = 6.0\%$$

(b) Wt. of sand to fill hole and funnel:

$$W_s = \frac{W_o - W_f}{453.6 \text{ g./lb.}}$$

Example:

$$W_s = \frac{(7457 \text{ g.}) - (4314 \text{ g.})}{453.6 \text{ g./lb.}} = 6.93 \text{ lb.}$$

(c) Volume of hole:

$$V = \frac{W_s}{D_s} - V_c$$

Example:

$$V = \frac{(6.93 \text{ lb.})}{(96.4 \text{ lb./cu. ft.})} - (.0407 \text{ cu. ft.})$$

$$= .0312 \text{ cu. ft.}$$

(d) Wet Density, lb./cu. ft.:

$$D_w = \frac{W_t}{V}$$

Example:

$$D_w = \frac{2.87 \text{ lb.}}{0.0312 \text{ cu. ft.}} = 92.0 \text{ lb./cu. ft.}$$

(e) Field Dry Density, lb./cu. ft.

$$D_d = \frac{D_w}{100 + W} \times 100$$

Example:

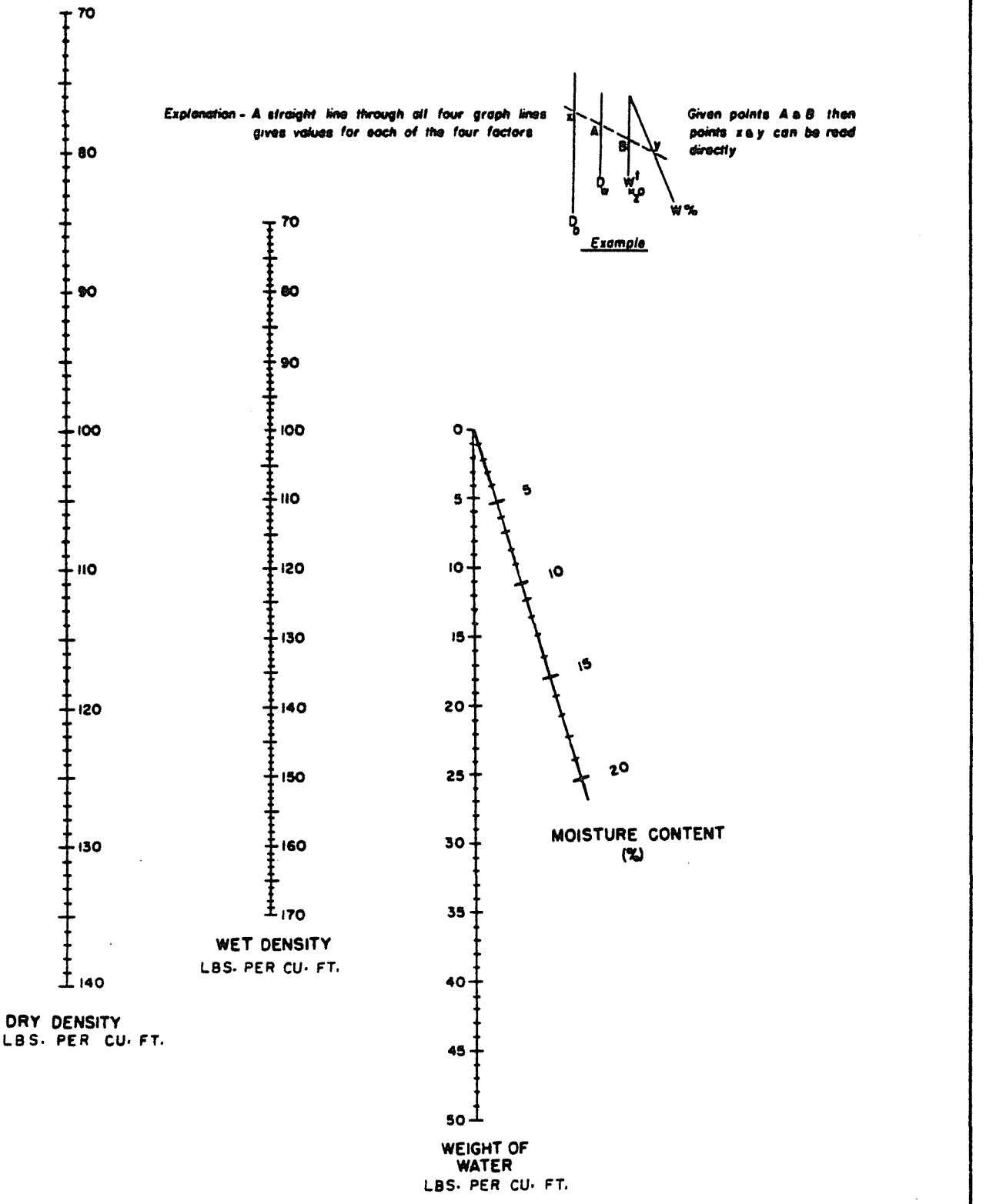
$$D_d = \frac{92.0 \text{ lb./cu. ft.}}{1.06} = 86.8 \text{ lb./cu. ft.}$$

(f) % compaction $= \frac{D_d \times 100}{\text{Maximum dry density}}$

Example:

$$\% \text{ compaction} = \frac{86.8 \text{ lb./cu. ft.}}{81.5 \text{ lb./cu. ft.}} \times 100 = 107\%$$

NOTE: *See conversion chart, Fig. 2 on the following page, which will be of aid in eliminating some of the calculations.*



MOISTURE DENSITY RELATIONSHIP

ADAPTED FROM BUREAU OF RECLAMATION

Fig. 2